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Pressure Bomb Measurements Indicate Water Availability in a Southwestern Riparian Community

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In spring and summer, soil moisture availability is the most important environmental variable affecting plant moisture stress. The Scholander pressure-bomb technique detected differences in plant moisture stress between and among species, thereby delineating areas of high or low potential evapotranspiration within a riparian zone.

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Composition of riparian communities in the Southwest is determined primarily by geography, minimum and maximum temperatures, soil moisture conditions, and flood disturbances. To a lesser extent, composition is affected by competition between and within species for light, water, and nutrients (Campbell and Green 1968). Specific microclimatic conditions within most of these communities are not known.

In 1970 and 1971, the microclimate of a riparian community was studied in detail at Sycamore Creek, near Sunflower, Arizona (elevation 3,400 feet). The objectives of the study were to determine (1) ecological and plant-water relationships of a relatively stable riparian community, and (2) environmental factors which most consistently affect the plant moisture stress of plants within this community.

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Study Area and Methods

The study area consisted of a 1-acre plot with a mixed stand composed of sycamore *(Platanus wrightii)*, cottonwood *(Populus fremontii)*, ash *(Fraxinus pennsylvanica)*, and walnut *(Juglans major)*, dominant because of their relative crown height over subordinate Utah juniper *(Juniperus osteosperma)*, mesquite *(Prosopis juliflora)*, desert willow *(Chilopsis linearis)*, and hackberry *(Celtis reticulata)*. In addition, Arizona white oak *(Quercus arizonica)*, shrub live oak *(Q. turbinella)*, catclaw mimosa *(Mimosa biuncifera)*, skunkbush sumac *(Rhus trilobata)*, poison ivy *(R. radicans)*, catclaw acacia *(Acacia greggii)*, and prickly pear cactus *(Opuntia engelmannii)*, are widely scattered throughout the plot. Sycamore, mesquite, and juniper immediately surrounded a ground-water well with a water table at generally less than 10 feet depth. The roots of all three plants were assumed to penetrate to the capillary fringe at about 6 feet below the ground surface.

The alluvial soil at the well site was 28 feet deep. The hackberry monitored was located some 120 feet from the well near the base of a mountain, and was believed to be growing in parent material and obtaining moisture solely

from local precipitation. Consequently, the sycamore, mesquite, and juniper monitored were expected to react simultaneously to moisture stress or atmospheric changes, while hackberry was expected to show the effect of drought conditions preceding the summer rains.

Soil temperature at the 20-inch depth, and air temperature at 3, 6, and 18 feet from a centrally located steel tower, were measured with thermocouples at bihourly intervals during 24-hour periods. Crown temperatures of each of the four species were measured at two-thirds the individual tree height. Sap temperature was measured 0.5 inch beneath the outer bark on the north side of the trunk at a 3-foot height. Vapor pressure deficit was calculated from temperatures taken at 3 feet. Net radiation was determined at 18 feet on the tower, and direct solar radiation at 8 feet in a natural clearing 125 feet from the tower. An estimated 95 percent of direct radiation was recorded; 5 percent of potential was lost because of shadows cast by adjacent canyon hillsides.

Plant moisture stress (PMS) was determined at bihourly intervals during daylight hours and occasionally at night with a pressure bomb (Scholander et al. 1964, 1965; Campbell and Pase 1972). The pressure bomb data formed the dependent variables in later analyses. Windspeed and other temperature values were not included in the analyses because they apparently did not change PMS. Windspeed was never less than 0.3 foot per second for any 4-hour period nor greater than 7.2 feet per second. Higher windspeeds always preceded summer convectional storms, but they did not appear to materially influence PMS. Precipitation always reduced PMS, probably because atmospheric stress declined as a result of change in vapor pressure deficit during the rain rather than because of the additional soil moisture.

Results and Discussion

We found that PMS of all four species reacted differently but usually consistently to atmospheric changes. Hackberry, as expected, showed the effects of apparent limited soil water. Juniper at this site has a wide tolerance for light, soil moisture, and soil types. It is found scattered on adjacent chaparral slopes, and is the dominant understory plant beneath the taller sycamore, ash, and walnut. Juniper showed more drought stress than expected, apparently because of a high transpiration-root absorption ratio.

Depth to water table at the well ranged between 9 and 11 feet from March to October. Diurnal fluctuations began the latter part of March and peaked at 0.09 foot in June. Diurnal and seasonal water-table fluctuation followed the cyclic course of evapotranspiration: slight diurnal fluctuations in the spring, with progressively larger fluctuations during high radiation loads in the summer. Cloudy and cooler days in the fall steadily reduced the diurnal fluctuations until they ceased between October and March.

Radiation loads increased progressively between spring and summer, and tended to taper off during the monsoon season in July, August, and early September. PMS followed this trend and usually was correlated with radiation intensity. Because of other environmental influences, however, PMS could not be accurately predicted from radiation values alone.

Average bihourly bomb values for the entire growing season showed hackberry with a mean PMS of 24.2 bars, consistently higher than either mesquite, juniper, or sycamore, with 16.7, 16.4, and 15.6 bars, respectively. Differences in PMS between hackberry and the other species were greater at 0600, 0800, and 1000 hours than at 1200, 1400, 1600, and 1800 hours. Averaged bomb values for the morning period were 23.3 bars for hackberry and 13.2 bars for the other species. Afternoon PMS averaged 24.8 bars for hackberry and 20.1 for the others.

PMS values among sycamore, mesquite, juniper, and hackberry were similar during winter dormancy. In the spring, however, leaves developed at different times and rates, causing PMS to vary. In May and June, PMS of the three species growing over a shallow water table, where both soil moisture and root aeration were favorable, tended to be closely correlated. PMS of hackberry was much higher. In July and August, when leaf maturation was similar between all species, PMS differences were less pronounced. Cloud cover reduced radiation which likely helped to reduce PMS in all four species. By September and October, PMS of hackberry, growing without the aid of a shallow water table, was highly correlated with that of sycamore, mesquite, and juniper either because of reduced radiation during partially cloudy days or extra soil moisture from precipitation.

At night, during May, June, and July, PMS among the four species was either highly negatively correlated or nonsignificant. At night, in August, September, and October, PMS among all species was highly correlated.

Radiation and vapor pressure deficit peaked at about 1400 hours, when PMS values were expected to vary greatly among species (table 1). Temperatures within the canopy of all species rose gradually from dawn until 1400 hours and declined thereafter. During the morning, temperature within the canopy of hackberry was not significantly greater than in sycamore, but sycamore, mesquite, and juniper crowns were warmer than hackberry during afternoon hours which may account for their greater rise in PMS. Apparently, the closed canopy formed by sycamore, mesquite, and juniper allows less incoming radiation to be reflected than at the open and exposed hackberry site. Similar observations in mesquite versus openings between stands were observed by Tromble and Simanton (1969).

Apparently, lack of soil water near hackberry caused PMS divergence from the other species sampled. The relationship between water availability in plants and root resistance, soil salts, low water conductivity in unsaturated soil, and stomatal and cuticular transpiration is very complex; PMS serves only as an index to these interrelated factors. Differences in PMS were greater among species in spring and summer before rains began (table 1). Also, from May through August, hackberry did not recover from high daytime stresses as quickly as the other three species. By September and October, 1800-hour values were nearly identical for the three species, but were still comparatively high for hackberry.

In 1972, bomb data from six additional mesquite trees near the study site varied widely. Some plants obviously tapped the ground water and others probably depended upon local precipitation. Because these plants were widely spaced from the ground-water well, soil moisture availability was not known. Although PMS values among the mesquites were obviously different, there were no visually apparent physiological differences. It appears that site location and availability of capillary water may have as much or more effect on PMS (and, consequently, on evapotranspiration rates) as actual species selection.

Table 1.--Summary of plant moisture stress, direct radiation, and vapor pressure deficit data on Sycamore Creek, central Arizona, 1971

Seasons and hours	Plant moisture stress				Vapor pressure deficit	Direct radiation
	Sycamore	Mesquite	Juniper	Hackberry		
	- - - - - - *Bars* - - - - - -				*inHg*	*ly/min*
SPRING (May-June)						
0600	7.7	9.6	10.4	23.9	0.30	0.0
1000	17.3	16.6	18.3	25.9	.78	.37
1400	16.4	19.9	22.6	28.4	.91	1.25
1800	11.6	13.3	12.5	31.0	.78	.53
SUMMER (July-Aug.)						
0600	4.5	11.0	19.0	22.6	.23	0.0
1000	13.0	24.6	20.0	40.4	.54	.26
1400	21.9	32.0	27.0	33.5	.85	1.12
1800	7.9	8.8	18.7	24.1	.48	.50
FALL (Sept.-Oct.)						
0600	3.1	5.9	6.6	5.7	.13	0.0
1000	23.3	25.0	18.6	27.2	.49	.45
1400	25.5	29.4	22.6	29.0	.72	.83
1800	7.2	9.2	11.6	23.5	.54	.30

Implications

From bomb data we can determine which plants are under how much stress. This stress occurs because of atmospheric conditions, water quality or availability, or inherent morphological and physiological characteristics of the particular species. But in general, water availability is the variable most likely to change from site to site. Because stresses change with seasons, single readings do not portray a clear picture. A seasonal series of bomb readings, however, indicates which plants are under drought stress. Thus the bomb technique can serve as a useful survey tool to determine relative availability of water to individual plants or species. With this information a map can be drawn on each stream sector depicting those areas of the flood plain where plants have additional soil moisture available. Such a map would indicate areas of highest potential water loss within the riparian zone.

Our measurements and analyses of the riparian microclimate did not reveal plant-soil-water conditions accurately enough to reliably predict plant moisture stress (PMS). PMS of plants utilizing shallow ground water usually responds similarly to changing radiation and vapor pressure deficit. PMS of hackberry, however, with an apparent soil moisture deficit, was seldom correlated with either radiation or vapor pressure deficit. Neither air, leaf, or crown temperatures, nor windspeed could be used to predict PMS reliably.

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